NAVAL BASE PHILADELPHIA-PHILADELPHIA NAVAL SHIPYARD,
DRYDOCK No. 4
League Island
Philadelphia
Philadelphia County
Pennsylvania

HAER No. PA-387-D

HAER
PA
51- PHILA,
709D-

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Department of the Interior
P.O. Box 37127
Washington, D.C. 20013-7127

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HISTORIC AMERICAN ENGINEERING RECORD

NAVAL BASE PHILADELPHIA - PHILADELPHIA NAVAL SHIPYARD, DRYDOCK No. 4

HAER No. PA-387-D

Note: The history reports for Drydock No. 4 and No. 5 are identical because these structures were built at the same time using the same technique.

Location:	South end of Bridge Street south of Porter Avenue, Philadelphia Naval Shipyard on League Island at the confluence of the Delaware and Schuylkill Rivers, in the City of Philadelphia, County of Philadelphia, Pennsylvania.
UTM Coordinates:	Zone Easting Northing 18 483675 4415030 Quad: Philadelphia, PA. - N.J. 1:24000
Date of Completion:	1943
Foundation/Construction:	Steel Piles/Concrete
Designer:	F. R. Harris
Engineers/Contractors:	Drydock Associates, Philadelphia
Present Owner:	Commander, Naval Base Philadelphia - Department of the Navy
Present Use:	Currently available for use. Dock is 1081 feet long, 130 feet wide and 51 feet deep.
Significance:	This rectangular drydock has a vertical concrete wall and a flat concrete floor formed on steel pilings. It is an example of a large World War II era drydock built using the tremie method developed by F.R. Harris, Rear Admiral, U.S. Navy.
Historian:	Robert C. Stewart, July 1994
Project Information:	This documentation project is part of the Historic American Engineering Record (HAER), a long range program to document historically significant engineering and industrial works in the United States. The HAER program is administered by the Historic American Buildings Survey/Historic American Engineering Record Division (HABS/HAER) of the National Park Service, U.S. Department of the Interior. The Naval Base Philadelphia -

Philadelphia Naval Shipyard recording project was cosponsored during the summer of 1994 by HABS/HAER under the general direction of Dr. Robert J. Kapsch, Chief, and by Naval Base Philadelphia, under the command of Rear Admiral Louise C. Wilmot.

The field work, historical reports and photographs were prepared under the direction of project leader Dean Herrin, HAER Historian and Craig Strong, HAER Architect. The recording team consisted of Robert C. Stewart, Historical Archaeologist, West Suffield, CT. The historical section of the report was produced by John Bacon, Philadelphia Maritime Museum and Robert C. Stewart. Jet Lowe, HAER, was responsible for formal photography. The interpretive drawings were delineated by Doug Anderson.

Others who contributed their time, advice, documents and help were: Jane Allen (Philadelphia Maritime Museum), Dan Cashin (Chief, Rigger Apprentice Training), Alfred Cavallero (Manager Design Branch-Public Works Engineering), Rich Chlan (Public Affairs Officer-PNSY), Ed Delany (Fire Administration), Ralph Edelman (Quality Assurance), John Fedak (coppersmith), Robert Gorgone (Deputy Business and Strategic Planning Officer-PNSY), John Hilliard (upholsterer), Ed Jones (Boilermakers), Frank Matusik (Foreman - Lofting), Frank Mellert (Architect - Public Works Engineering), Rosalie Moschella Pinto (Tacker - retired, 26 shop), Paul Niessner (Equipment Specialist - Cranes), Ed Ochmanowicz (Superintendent 31 Shop - Inside Machining), Steve Pandur (Leadingman - Fabric Workers - Sail Loft), Elaine Pelagruto (Beacon Editor), Tom Pierson (Loftsman), Cece Saunders (Historical Perspectives), Richard Scardino (Leadingman -11 shop - ship fitting), Martin Sheeron (Superintendent - Boilermakers), Commander Walter T. Talunas, USNR (Human Resources Transition Coordinator).

For additional information, see the following HAER documentation:

HAER No. PA-387	NAVAL BASE PHILADELPHIA - PHILADELPHIA NAVAL SHIPYARD (Overview, includes bibliography)
HAER No. PA-387-A	NBP-PNSY, DRYDOCK No. 1
HAER No. PA-387-B	NBP-PNSY, DRYDOCK No. 2
HAER No. PA-387-C	NBP-PNSY, DRYDOCK No. 3
HAER No. PA-387-E	NBP-PNSY, DRYDOCK No. 5
HAER No. PA-387-F	NBP-PNSY, 350-TON HAMMERHEAD CRANE
HAER No. PA-387-G	NBP-PNSY, 3,000-POUND CRANE
HAER No. PA-387-H	NBP-PNSY, MANAGEMENT ENGINEERING (Bldg. No. 4)
HAER No. PA-387-I	NBP-PNSY, SUPPLY DEPT. STOREHOUSE (Bldg. No. 5)
HAER No. PA-387-J	NBP-PNSY, COMMANDER'S OFFICE-NAVAL BASE (Bldg. No. 6)
HAER No. PA-387-K	NBP-PNSY, STEEL STOREHOUSE (Bldg. No. 8)
HAER No. PA-387-L	NBP-PNSY, CARPENTRY SHOP (Bldg. No. 14)
HAER No. PA-387-M	NBP-PNSY, MACHINE SHOPS (Bldgs. No. 16 & 18)
HAER No. PA-387-N	NBP-PNSY, MACHINE SHOPS (Bldgs. No. 17 & 19)
HAER No. PA-387-O	NBP-PNSY, FOUNDRY/PROPELLER SHOP (Bldg. No. 20)
HAER No. PA-387-P	NBP-PNSY, STRUCTURAL SHOP (Bldg. No. 57)
HAER No. PA-387-Q	NBP-PNSY, AIRCRAFT STOREHOUSE (Bldg. No. 76)
HAER No. PA-387-R	NBP-PNSY, AIRCRAFT ASSEMBLY SHOP PLANT No. 2 (Bldg. No. 77H)
HAER No. PA-387-S	NBP-PNSY, STRUCTURAL ASSEMBLY SHOP (Bldg. No. 541)
HAER No. PA-387-T	NBP-PNSY, PIPE COPPERSMITH SHOP (Bldg. No. 543)
HAER No. PA-387-U	NBP-PNSY, MATERIAL ASSEMBLY SHOP (Bldg. No. 592)
HAER No. PA-387-V	NBP-PNSY, MAIN SUPPLY WAREHOUSE (Bldg. No. 624)
HAER No. PA-387-W	NBP-PNSY, RESERVE BASIN AND MARINE RAILWAY

DRYDOCK Nos. 4 & 5

In 1927, F. R. Harris, Rear-Admiral, USN, developed the tremie technique of drydock construction. Tremie refers to a technique for pouring concrete under water. This eliminates the problems with keeping the site dry while it is under construction and reduces the possibility of landslides and displacement of the drydock floor from hydrostatic forces.

Harris' method was a relatively simple, safe and efficient construction method for drydock construction. It proved to be a time-saver and allowed the construction of large drydocks in about two years, generally within cost estimates.

Construction began by dredging basins at the sites of Drydocks 4 and 5. The bottom of each basin was covered with a gravel bed 2 feet thick. Pile drivers positioned steel "H" beams in the overlying water and forced them through the gravel bed to a firm soil stratum below the river-bank. These piles were for carrying the loads of the drydock and any ship within it.

Cranes positioned steel tremie forms, extending for the full width of the drydock and its side walls, on the submerged gravel bed. Concrete was pumped into the floor forms. After the concrete had set, tremie forms were positioned at the sides of the floor forms and filled with concrete. When the concrete in the tremie wall forms hardened, the space between the side walls and the excavation was backfilled.

The drydock entrance was blocked with a coffer dam and the water pumped out so work could proceed under dry conditions. Masons formed a concrete lining on the inside of the wall tremie forms as well as on the floor. This compensated for irregularities in tremie form alignment and covered the surface of concrete. It gave a finished appearance to the wall and floor surface.

Wartime ship construction activity was well underway while Drydock No. 4 was being finished. The tremie method allowed six destroyer escorts to be built in the partially finished dock while it was rushed to completion.

The tremie method of drydock construction, as developed by Admiral Harris, allowed drydocks to be built in about two years with predictable costs. The engineering firms of Moran, Proctor, Freeman and Mueser; Parsons, Klapp, Brinkerhoff and Douglas; and Fay, Spofford and Thorndike worked with Harris in developing tremie drydock construction technique.

For a list of related sources, see the bibliography at the end of the written report for HAER No. PA-387, Naval Base Philadelphia - Philadelphia Naval Shipyard.

ADDENDUM TO
NAVAL BASE PHILADELPHIA -
PHILADELPHIA NAVAL SHIPYARD,
DRY DOCK NO. 4
Broad Street south of Government Avenue
Philadelphia
Philadelphia County
Pennsylvania

HAER No. PA-387-D

HAER
PA
51-PHILA
709D-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Philadelphia Support Office
200 Chestnut Street
Philadelphia, PA 19106

HISTORIC AMERICAN ENGINEERING RECORD

NAVAL BASE PHILADELPHIA-PHILADELPHIA NAVAL SHIPYARD, DRY DOCK NO. 4

This report is an addendum to a 4-page report previously transmitted to the Library of Congress.

Location: Broad Street south of Government Avenue, Philadelphia, Philadelphia County, Pennsylvania

UTM Coordinates:

Zone	Easting	Northing
18	483535	4415025

Quad: Philadelphia, Pa.-N.J. 1:24,000

Dates of Construction: June 1940-May 1942

Foundation/Construction: Steel piles and tremie forms/Concrete

Designers/Engineers: Dry Dock Engineers (New York)

Contractors: Dry Dock Associates

Present Owner: Department of the Navy
Naval Facilities Engineering Command
10 Industrial Highway
Lester, Pennsylvania 19113-2080

Present Use: Vacant

Significance: Dry Dock No. 4 is one of a series of very large dry docks constructed at United States Navy yards during World War II to meet shipbuilding and repair needs. It, along with other contemporary dry docks, was built using the tremie method of concrete construction, developed by Rear Admiral Frederic R. Harris (USN-Ret.).

Project Information: Dry Dock No. 4 has been determined to be a contributing resource within the Philadelphia Naval Shipyard Historic District. It is located in a portion of the former Philadelphia Naval Shipyard presently under redevelopment as the site of the Kvaerner Philadelphia Shipyard, a commercial shipbuilding operation. Kvaerner plans to reuse Dry Dock Nos. 4 and 5 in its operations. To mitigate changes that would result from reuse, the Pennsylvania Historical and Museum Commission and the Department of the Navy agreed to record Dry Dock No. 4 to HAER standards.

Preparers of Documentation: Richard Meyer/Senior Project Manager
Douglas C. McVarish/Project Architectural Historian

John Milner Associates, Inc.
535 North Church Street
Philadelphia, Pennsylvania 19380

1999

Description of the Feature

Philadelphia Naval Shipyard Dry Dock Nos. 4 and 5 are both graving docks. Frederic R. Harris defined a graving dock as "a basin which excludes water with tight walls, or sides, and head, and a closure gate so that the water can be removed by pumping" (Harris 1942:309). Dry Dock No. 4 is 1,092 feet long from the head wall to the inner face of the caisson, 152 feet 7 inches wide at coping, 143 feet 2 inches wide 6 feet above the sill, and 47 feet 9 5/8 inches deep. Dry Dock No. 5, its near twin, is 1,092 feet 6 inches long from head wall to inner seat of the caisson, 151 feet 8 inches wide, and 51 feet 3 inches feet deep. The sills of the two dry docks are 33.8 feet below low water.

The outside walls of Dry Dock No. 4 are constructed of tremie concrete of 15 foot thickness. The bottom of the dry dock is constructed of a 14 foot thickness of tremie concrete laid atop a gravel bed. Steel piles project through this gravel bed and are anchored in the subsurface. The structure of the tremie forms is evident in the narrow openings extend across the floor of the dry dock at the edge of each tremie form. A concrete lining, placed in the dry dock, forms the outer surface of the floor and side walls. Drainage gutters run the length of the dry dock in the vicinity of the side walls. These gutters are covered with steel grates. A removable chain rail extends around the coping of the dry dock. Mooring cleats are spaced along the top of the side walls of the dry dock at points where the outside of the coping angles outward.

The river end of a dry dock is referred to as its entrance. Typical of dry dock entrances, the side walls of the entrance to Dry Dock No. 4 are angled outward from the base. These walls slope at a rate of 3.5 feet to 31 linear feet. Such inclined walls facilitate the seating and unseating of the caisson. The bottom of the caisson rests on a seat and bears against a sill. The entrance seat has a line of sheet steel piling located below it to prevent undermining caused by erosion or dredging (U.S. Department of Commerce 1956:2-4).

The entrance to the dry dock is closed by a floating caisson, a watertight structure whose buoyancy can be altered by varying its water ballast. The caisson of Dry Dock No. 4 is constructed of steel and is similar in construction method to that of all-welded steel vessels. This caisson was built by Dravo Corporation, a Pittsburgh based firm that had substantial experience in building naval craft during World War II. Sheathed in steel skin plate, it measures approximately 157 feet in width, 53 feet 2 inches tall, and 20 feet wide. The outer edges of the caisson slope inward, and the bottom corners are rounded. The lower portion of the outboard elevation of the caisson slopes inward.

A walkway with steel pipe railings extends across the top of the caisson. This walkway is illuminated by two light standards with paired lamps. The west light standard also contains a red signal light. Two round manholes provide access to portions of the interior of the caisson, while two, slightly raised, rectangular hatches provide access to three flights of ladder-like steel stairs in the interior of the caisson. Two capstans are also placed atop the caisson. These 7.5 horsepower capstans were manufactured by the New England Trawler Equipment Company. Attached 1/2 horsepower "Pacemaker" motors were manufactured by Dings Dynamic.

The machinery of the floating caisson consists of pumps and valves, used primarily to vary the water ballast, and capstans, to aid in moving the caisson while afloat. Sinking valves are operated from control stations, and pump motors drive 15-inch, centrifugal pumps. The water-flow regulation system of the caisson is designed to maintain firm control of list and trim during all stages of sinking and raising operations. The motors obtain their power through cables attached to shore connections located next to the caisson seat.

The operation of raising the caisson from its seat is begun when the water level inside the dry dock reaches the level of the water seaward of the caisson. The pumps are started with the seaward discharge valves open, and sufficient water ballast is removed to float the caisson to its desired position. Then the valves are closed and secured, the caisson machinery is shut down, and the caisson is moved outside the dry dock channel limits by tugs and/or capstans.

The operation of closing the entrance to the dry dock is the reverse of the opening operation except that pumps are not used to flood the ballast tanks to sink the caisson. While the caisson is being sunk, it must be kept exactly in its correct position with respect to the sill and have practically no list or trim (U.S. Department of Commerce 1956:2-10-2-11).

The dry dock is flooded through flooding tunnels located in the side walls. These basically rectangular tunnels measure seven feet wide and six feet high through most of their lengths. The tops of these tunnels lie several feet below low water, and their openings are located in the outward face of the entrance walls. The openings are protected by heavy gates or grills known as trash racks to prevent debris from entering the tunnel. Flow of water into the flooding tunnels is controlled by sluice gates. A sluice gate moves between two parallel, machined metal guides that form part of its frame. The frame is bolted to thimbles embedded in the concrete. The sluice gates for Dry Dock No. 4 are located near the entrance to the flooding tunnel inside the trash rack and stoplogs.

The set of grooves for stoplogs is located in the flared section at the end of the flooding tunnels. The purpose of these stoplogs is to exclude sea water from the tunnel system if the sluice gates fail to operate and also to provide dewatered conditions for the performance of maintenance operations on the gates.

The sluice gates are opened by an electric motor. This 440 volt, 3 phase, 60 cycle motor was specified to raise the gates at a rate of no less than one foot per minute. The gate mechanism also permits emergency manual operation. The sluice gate is electrically operated by a three-position switch with positions for closing, opening, and off. A mechanical indicator shows the amount of opening. The switch and indicator are mounted on the central control board in the pump well (U.S. Department of Commerce 1956:2-19).

The filling tunnels or culverts extend from the entrance walls of the dry docks to a point approximately 200 feet north of the entrance wall. Filling and drainage units are located 152 feet, 176 feet, and 200 feet from the sill. At these locations, cylindrical steel pipes, four feet in diameter, extend downward from the bottom of the culvert to a point below the floor of the dry dock. The pipes widen to 5 feet at the bend at the bottom of the side walls and to six feet beneath the floor of the dry dock. Water flows into the dry dock through six metal floor grates located adjacent to the gutters. The total estimated time needed to flood the dry dock is 90 minutes. The three floor grates near the west wall measure 9 feet by 20 feet, while those near the east wall measure 6 feet by 15 feet. The waste water flows through the same floor grates to the pump well through culverts that measure nine feet in diameter. An eight foot by nine foot discharge conduit empties the waste water from the pump well into the Delaware River.

The dry dock is dewatered by three 54 inch, 1,200 horsepower, 390,000 gallon per minute dewatering pumps. The same pumps also serve Dry Dock No. 5. These are mixed-flow-type, centrifugal pumps driven by motors. The motors, located on the pumphouse floor above the pumps, drive the pumps by means of vertical steel shafts. The 2,300 volt, 3 phase, 60 cycle squirrel cage motors operate at 1,200 rpm. The total estimated time to dewater the dry dock is 180 minutes. Dry dock drainage is provided by two 16 inch, 250 horsepower, 20,000 gallon per minute, mixed flow type pumps. The same pumps are also used to drain Dry Dock No. 5. These pumps are designed to clear the dock floor fairly quickly and to remove leakage. The drainage pumps are powered by 440 volt, 3 phase, 60 cycle, 250 horsepower, moisture-resistant, squirrel cage type motors.

Both side walls also contain pipe tunnels. Each pipe tunnel contains a 6 inch diameter fresh water main, a 6 inch diameter steam main, a 6 inch diameter air main, and an 8 inch diameter salt water main. A subterranean utility tunnel formerly connected the 6 inch steam main, the 6 inch fresh water main, and the 8 inch salt water main in the east wall of the dry dock to Building 541, while the four mains on the west side of the dry dock were connected to the dry dock service building, Building 620. At the south end of the west wall, 3 inch fresh water, 3 inch steam, and 3 inch air pipes connected to the pump house building (Building 733). At various points along the walls, 4 inch sludge suction pipes connected to sludge pits.

Utilities serving the dry dock include electricity, fresh water, river water, compressed air, steam, oxygen, and MAPP gas. Alternating current electricity is of the 3 phase, 60 hertz type and is provided at 460 volts and 14,250 amps. Receptacles include two 4,000 amp buses on the east side and 17 east side and 22 west side 400 amp receptacles.

Fresh water is provided by 6 inch mains capable of delivering 800 gallons per minute at 45 psi. Twenty-four 2 1/2-inch outlets are provided in each side wall. River water is provided by 12 inch mains capable of delivering 7,000 gallons per minute at 175 psi. River water outlets include 18 4-inch high pressure and 24 2 1/2-inch low pressure outlets on each side. Compressed air is provided by 6 inch mains capable of delivering 10,000 cubic feet per minute at 100 psi. The dock is served by 144 1 1/4-inch outlets. Steam is provided by 6 inch mains capable of delivering 80,000 phr at 100 psi. The dock is served by 44 two-inch outlets. Oxygen is provided by 2 and 3 inch mains that deliver the gas at 800 cubic feet per minute at 100 psi. The dock is equipped with 36 3/4-inch outlets. MAPP gas is provided by 2 inch mains at 5 pounds per square inch. The dock is equipped with 22 3/4-inch outlets on the east side and 19 outlets on the west side (NFEC 1981:29.3-105).

Service altars, approximately four foot wide wall niches that run the length of the side walls, are located near the tops of the walls. Steel pipe railings extend along the outer edges of the service altars. A 4 foot by 7 foot service altar also extends the width of the head wall.

Service niches are placed in the rear walls of the altars and range in width from four feet to 57 feet. These niches provide necessary utilities, including 450 volt, 400 amp ship service; 115 volt, 400 amp ship service; 115 volt 500 watt lighting service; telephone service; sluice gate control cables; lighting distribution panels; and lighting service panels. The service altar also contains connections from the pipe tunnel for salt water, fresh water, air, and steam lines.

Flood lights are mounted on the dry dock walls above the altars. The tops of the pipe tunnels are 3 feet below the lip of the dry dock, while the tops of the altars are 2 feet six inches below the lip of the dry dock. The tops of the filling culverts are located 13 feet from the lip of the dry dock. Original, white and blue ceramic tile, water level indicators are located on the side walls just inside and outside the caisson seats, while modem water level indicators are located on both walls near the head wall of the dry dock. These water level indicators are supplemented by gages on the pump well control board, activated by pressure-sensitive bulbs located near the tile indicators (U.S. Department of Commerce 1956:2-20). Timber bumpers are anchored to the base of the service altars and to the top of the side walls of the dry docks.

Sewage is discharged from the dry dock through floor drains spaced along the east side of the dry dock floor and by ship connections spaced along the west side of the dry dock floor. A total of 88 floor drains are used, spaced 12 feet apart, while 24 ship connections are used, spaced 36 feet apart. The ship connections are protected by steel cover plates. The sewage is carried away beneath the floor of the dry dock in 8 inch diameter cast-iron pipes. Sludge is carried away from service altar connections by means of 4 inch diameter sludge suction pipes to sludge pits located away from the dry dock walls.

Steel-framed stairways with three intermediate landings provide access to the floor of the dry dock from its northeast and northwest comers. These stairways are bolted to the wall of the dock, and the intermediate landings are supported by steel brackets reinforced with crisscross channels. The top flight of stairs contains 13 treads; the second, 17 treads; the third, 17 treads; and the bottom, 18 treads. These stairways have steel pipe railings and 3 foot 10 inch deep landings. Center stairs, originally located on the east and west walls approximately 559 feet from the sill, have been removed. South stairs, similar in character to the north stairs, are located approximately 307 feet from the sill. These south stairs have four landings, instead of the three landings of the north stairs. Steel-framed welding balconies originally extended seven feet out from the side wall of the dry dock and were supported by triangular brackets bolted to the side walls of the dry dock. These balconies have been removed, although the piping remains for the welding platforms. A total of twelve welding set platforms were provided in the dry dock, six on each side. The northern platforms, 40 feet in width, were centered 180 feet from the head of the lock. The middle platforms, 80 feet in width, were centered 370 feet from the head of the lock, while the southern platforms, 40 feet in width, were centered 180 feet from the sill of the lock. These platforms were presumably removed to allow wider ships to be accommodated within the dry dock.

Each of the welding platform locations is serviced by a network of pipes, most of which extend from the back wall of the service altar. A horizontal, cylindrical steel pipe extends horizontally along the front of the altar and forms an inverted U, at the center of the welding platform. Valves are located on either side of this U, and a vertical pipe, also equipped with a valve, extends downward from the middle of the U. Each of these vertical pipes intersects with a horizontal pipes mounted near the bottoms of the side walls of the dry docks.

The dry dock is equipped with a total of nine capstans. One is located at the head, one to each side of the entrance, and three along each side wall of the dry dock. These capstans, each of which is operated by an electric motor, are used for pulling vessels and caissons by means of ropes or cables that wind around the center portion of the capstan barrels. Only the barrel portion of the side wall capstans are exposed. The capstan machinery is located in a protected housing beneath ground level (U.S. Dept. of Commerce 1956:2-20-21).

In a graving dock, means must be provided to keep a docked vessel sufficiently above the floor level to permit work on her bottom. The vessel must be supported off the floor in such a way that its frame and skin remain unstressed. This requires supports that can be set in differing positions and placed fairly close together. Primary support for vessels in Dry Dock No. 5, as other dry docks, is provided by keel blocks. The exact location of these keel blocks depends on the load distribution of the vessel. In general, the blocks are placed transverse to and under her main keel and are secured to the floor of the dry dock (U.S. Department of Commerce 1956:2-23).

Additional Historical Data

In their history of Naval construction during World War II, the anonymous authors described the state of U.S. Navy yards at the outbreak of World War II:

> The older navy yards, and to a lesser extent the more recent yards, had undergone progressive evolution and piecemeal development during the years, as the ships of the fleet evolved from the frigates and sloops of the Revolutionary days to the complex and varied types of the modern navy. Although they had undergone considerable expansion during World War I, none of the yards were fully equipped to cope with the building and repair requirements of the two-ocean Navy of World War II, and most of them were congested, obsolescent, and poorly arranged (U.S. Navy Bureau of Yards and Docks 1947b:169).

Between 1938 and 1945, a total of $590 million was expended for construction and improvements at U.S. Navy yards. These improvements were aimed at providing the facilities necessary for a planned large-scale ship construction program. Among the structures built to accommodate increased ship repair and construction were dry docks. The first of the major dry docks funded under these appropriations were at Puget Sound Navy Yard in Washington State. In 1938, work was begun on a 1,000 foot dry dock, No. 4, at the Puget Sound yard. A year later, construction began on a second large dry dock at the yard (U.S. Navy Bureau of Yards and Docks 1947b:173).

The Navy had used dry docks for ship repair and maintenance for many years, but it was not until the period immediately prior to World War II that dry docks were built for use in ship construction. An anonymous article in *Engineering News-Record* cited the advantages of a dry dock over the inclined shipways previously used:

> In a dry dock a ship can be built on a level keel, which simplifies the framing and assembling of the steel structure and eliminates the time consumed in computations and measurements necessary to insure members being in proper relation to each other as is necessary on inclined ways. The speed of erection is also accelerated as less bolting and bracing are required to hold parts in true positions while the riveting or welding is completed. Nor do temporary structural members have to be put into the ship to resist launching stresses as is necessary on way building. Finally, when ships are built in basins,

> the big guns and superstructures can be installed (limited only by the capacity of the dock cranes), whereas the use of ways requires that the addition of such heavy pieces be postponed until after the ship is launched. Launching from basins merely requires letting water in through tunnels, which are built into the side walls, after which the completed ship merely floats off the keel blocks (Anonymous 1942b:66).

The proposed U.S. naval ship construction program included five battleships of the *Montana* class, each with a true displacement of nearly 70,000 tons. The dimensions of these ships were predicated on the availability of the third set of Panama Canal locks. These ships would have had a beam greater than the clear space between the crane supports of existing shipways. To construct these vessels, it was necessary to provide either new shipways or shipbuilding dry docks. The latter alternative was selected to avoid the problems and hazards involved in launching such large ships and to gain advantages in ease of access, facility of construction, and simplification of weight-handling operations inherent in the use of dry docks.

Existing dry docks at Philadelphia and other navy yards were too small to accommodate this planned ship construction. Philadelphia's Dry Dock No. 1, built in 1889, is 448 feet long and 88 feet wide. Dry Dock No. 2, built in 1902 to 1908, is 721 feet long and 96 feet wide. Dry Dock No. 3, built in 1921, is 1,003 feet long and 118 feet wide (U.S. Navy Bureau of Yards and Docks 1945). During World War II, Dry Dock No. 1 was used for construction and repair of destroyers, frigates, submarines, and auxiliary craft; Dry Dock No. 2 for First Line Cruisers and large auxiliary craft; and Dry Dock No. 3 for battleships and first line aircraft carriers (Bureau of Yard and Docks 1947a:184).

In the summer of 1940 construction was begun on the first two super-docks, designed to accommodate the construction of large battleships. These docks were built at Norfolk and Philadelphia. Both were approximately 1,100 feet long and 150 feet wide. In 1941, a second shipbuilding dock was started at Philadelphia, two similar docks were constructed at the New York Navy Yard, and a similar dock was begun at the Naval Supply Depot, Bayonne, New Jersey. All of these docks were built by the tremie method and were completed in from 17 to 21 months. By comparison, prior dry docks required three to eight years of construction time (U.S. Navy Bureau of Yards and Docks 1947b:174-175).

In 1941, the U.S. Navy had a total of 697 vessels under construction. By July 1, 1942, this total had risen to 3,230. To accommodate the increased demands for ship construction, overhaul, and repair, the Navy contracted for the construction of 28 new shipbuilding and graving docks on the Atlantic and Pacific coasts (Anonymous 1943b:165). Strategy changes dictated the abandonment of the program for building super-battleships and the construction, instead, of aircraft carriers of the *Midway* class. A substantial number of carriers and other smaller vessels were built in the larger of these dry docks during World War II.

In May 1941, construction was begun on the second large dry dock at the Philadelphia Naval Shipyard. Dry Dock No. 4 was substantially underway by that time, and the Navy was anxious to start building ships in it. In order to allow shipbuilding to begin as quickly as possible, a temporary cofferdam was installed in the body of the dock to permit unwatering of the inboard end prior to the completion of the outboard end. This temporary cofferdam, completed on May 24, 1941, was constructed 860 feet from the head of the lock (U.S. Navy Bureau of Yards and Docks 1947:157, 189).

The cofferdam permitted the Navy to start construction on the middle portion and stern of ships, which, according to Dan H. Young, involved the most difficult and lengthiest work (Young 1941:44). Six destroyer escorts were built in the partially finished dry dock while it was rushed to completion.

The contract for Dry Dock No. 4 at the Philadelphia Naval Shipyard was awarded on June 26, 1940. The site was cleared and excavation was begun on July 3, 1940 (Young 1941:42). The dredging was completed on October 28, 1940 (Spencer 1942). A basin for the dry docks was excavated, extending about 900 feet back from the Delaware River bank. Excavation for the dry docks was carried to a depth of 58 feet below mean low water, 224 feet wide at the bottom and 436 feet wide at the top, the bottom width setting up a clearance of 20 feet from the outside of the tremie concrete walls on either side. About 1,273,000 cubic yards of material was dredged in operations at the site of Dock No. 4. Steel piles, 12-inch "H" sections, were driven to a penetration of 57 feet. Piling driving was completed on February 19, 1941. Tremie concrete was poured around the heads of the piles, which were used both for bearing and for resistance to uplift.

Construction methods used in both Dry Dock No. 4 and Dry Dock No. 5 were similar. Modifications were made on No. 5 in the light of experience on No. 4. On No. 5 the steel piles were cut before they were driven, thus eliminating costly and time-wasting cutting by divers. The thickness of the walls and floors of Dock No. 4 was 14 feet with a 2-foot finished lining, whereas the monolithic floor of No. 5 was 15.5 feet thick, and the lining was eliminated from the walls (U.S. Navy Bureau of Yards and Docks 1947b:188-189).

The process of construction of Dry Dock No. 4 was comprehensively described in a series of articles published in the engineering press of the United States and England in 1942 and 1943 (Anonymous 1942a, 1942b, 1943a, 1943b). Several of these articles are included as appendices to this documentation. The contents of these articles are summarized below.

The area on which the docks were built is made up of sandy silt, and accordingly, the dry docks are carried on piles. The driving of these piles and the whole of the construction of the docks up to a height of 5 feet below lowest level for the side walls was carried out under water. This underwater construction included the laying of the concrete floor and the building of the side and shore end walls.

The first stage of construction was the excavation of silt from the sites of the dry docks. This excavation was carried out by three dippers, one suction dredge, and two clamshell dredges. The material excavated by the dippers and clamshell dredges was loaded onto bottom-dump barges and dumped in deep water, while the suction dredge discharged through a floating pipe line to an old creek bed on the New Jersey side of the Delaware River. Excavation was carried to a depth of 63 feet below mean low water in the majority of the pit, and to 72 feet below low water in a small section.

Upon completion of dredging, an I-beam drag was used to smooth the trench bottom to a level floor. A minimum of 2 feet of crushed stone of uniform 2 to 3 inch size was placed on the bottom and then leveled with the I-beam drag to make the site ready for construction.

Piles were driven through this stone blanket to support the structure. These H-section piles, which measured 1 foot by 1 foot, were generally spaced about 6 feet longitudinally and 5 feet transversely. The piles weighed 74 pounds per linear foot and varied in length from 30 to 70 feet. A total of 6,825 piles, manufactured by Bethlehem Steel and Carnegie-Illinois Steel, are used to support Dry Dock No. 4.

The use of forms for tremie construction made it necessary that the piles be driven close to plan location and elevation to avoid interference with the structural members and the reinforcing in the form, and to provide supports that exactly matched the form bearing seats. The proper positions of the piles were located by means of cables stretched across the dock area that carried metal tags to mark the pile positions. A work float, rigidly attached to the front of the pile driver and extending several feet ahead of it, had a bulls-eye marked on it for centering a plumb bob under the cable and locating the leads over the pile location. The cable was kept at about 300 pounds tension, but on windy days a transit on shore was used to check against side deflection.

These piles were driven under water using an enclosed double-acting pile hammer that followed the pile down a telescopic extension of the floating pile driver. The piles were lowered to, and generally through, the rock blanket with little resistance. The hammer was employed to drive them as required. In some cases, the piles reached the specified depth without developing the required bearing. Usual practice in such cases was to drive one or more wood piles between the steel H-piles to consolidate the ground and thus to increase the skin friction.

A "tell-tale," reading in feet of elevation, was used on the pile drivers to indicate the depth at which the pile was located. The device used was a cable with one end hooked to the top of the hammer and extending over a sheave at the top of the leads to a graduated plate at the rear of the boat. As the pile was driven, an indicator moved along a bar and recorded blows per foot or per inch.

After driving, the position of the pile top was taken by checking the amount it was out of plan location. It proved necessary to cut several of the piles underwater. Divers used an underwater torch that burned hydrogen and oxygen.

A clamp of 2 inch wide steel, made to conform to the H-shape of the pile, was slipped over the pile to give a level guide support for underwater cutting.

It was necessary to provide forms for the concrete to be placed underwater, to divide the floor sections into reasonable size pours, and to confine the concrete. In addition, the design of the dry docks required heavy reinforcement and means to hold this reinforcement in place. These functions were combined in box trusses, designed to be picked up at two points and lowered into the water as a single unit. The steel of the truss served as part of the reinforcing and was supplemented by steel shapes and by reinforcing bars as large as 2 inches square. The structural frame was then enclosed by 3 1/2 inch deep, 18-gage, steel sheeting, welded on the sides and end. The form was built as long as the full width of the dock and walls, but had a frame at the wall line to separate the section under the walls from that under what would be the open dock. The forms were used only for alternate 14-foot wide sections; the concrete was placed later in the unformed areas. Reinforcing of the intermediate bays was cantilevered from the adjacent forms.

Because of congestion in the dry dock construction areas, the forms were assembled at an off-site fabricating yard. This yard was located on the water and allowed the forms to be moved to the project site by barge. The structural steel was received at the yard partly fabricated, and the units were assembled on three flatcars that moved along an assembly line. Sheeting and connections were welded on, reinforcing and other parts added, so that the assembly reached the dock as a finished unit.

Cars carrying the section of form were run directly on railroad car-transfer barges, and the units were jacked up and blocked to permit the cars to be released for use in fabrication of another unit. The barge, loaded with a single floor unit and two or more wall forms, was moved by tugs to the dry dock site. The completely assembled forms were quite heavy. Each form was approximately 12 feet wide, 14 feet high, and 184 feet long and weighed between 80 and 130 tons. Because they were long and narrow, they proved difficult to maneuver into position underwater.

Initially, the forms were placed by a floating naval crane using a lifting truss from a single point pickup, but this method was not entirely successful. Most of the truss setting was accomplished using three 60 by 90 foot sections of an old floating dry dock. The sides of these sections were removed, and stiff-leg derricks were mounted on two of them to form floating cranes. The two derricks were individually mounted on separate floating sections and could be used singly or together. The third floating section served as a spreader to make a rigidly connected unit. The derricks were widely spaced to set the long floor trusses.

The derrick boat was moored in position to set a section of form, and the car float was brought under the booms. After the floor unit was picked up, the car float was moved out, and the form lowered. Tower guides on the form, put in place while the structure was being fabricated, were lined up by instrument to locate the box underwater. Divers directed the underwater operation, using two-way telephones to instruct the surface crew. Setting proved tedious as the form had to rest on a single pile at each of its four corners. There was a maximum tolerance of three inches horizontally.

An interlocking section of form fabricated to extend the wall enclosure to 5 feet below the low tide level was constructed to fit over the bottom form. This piece was constructed in the same yard as the bottom forms and transferred to the site in alternate 56 and 28 foot lengths. It was fastened to the bottom form. The section of the form under the wall was designed with cantilevered sections at the ends, making it twice the width of the section under the dock. This made the wall form continuous. Bulkheads were placed so that concrete was poured in 42 foot lengths in the wall.

Original plans called for the tremie forms to rest neatly atop the crushed stone blanket. In reality, the stone blanket was disturbed by driving pilings through it, and minor depressions occurred along the edge of the form so that it would not hold the flowing concrete. The initial remedy was to attach a closed loop of expanded metal lath to the bottom of the form. When the form was lowered, the loop was expected to spread into a bulb shape and fill the irregularities. This technique proved only partially successful. Other methods were also tried until a canvas flap was developed. One end of the canvas flap was fastened near the bottom of the form along each interior face. A large hem in the other end held bags of stone. After the form was lowered into place the canvas flap was dropped to seal the joint between the foundation stone and the edge of the form. Although the flaps had to be supplemented by some hand-placed bags of stone, it proved most satisfactory of the methods tried.

To construct the dry docks, 500,000 cubic yards of tremie concrete had to be placed over an underwater area of ten acres in about five and one half month's time. The placing schedule called for 350 cubic yards of concrete per hour to be delivered to floating rigs for underwater placement. The peak production rate was 3,600 cubic yards per day. Because this rate was too fast for the associated work of fabricating and placing the tremie forms, it was stepped down to a production of about 2,700 cubic yards per day (Young 1941:104). To supply this large amount of concrete, the dry dock contractors selected a land plant which delivered aggregates and cement by barge. Mixing was done in five double-drum machines, and the concrete was pumped to specially constructed tremie placing barges.

Concrete for the job required seven bags of cement per yard and was made with one part cement, 1.7 parts sand, 2 parts one inch gravel, and .45 parts two inch gravel. Materials required for 350 cubic yards of concrete per hour included 440 tons of aggregate and over 600 barrels of cement. The aggregate used in dry dock construction was freighted in by water in 1,000 ton scows from the Warner Company plant in Morrisville, Pennsylvania.

Space limitations prevented the use of storage piles of aggregates. Instead, steel bins were constructed. The storage bins were long and narrow and had a 175-foot face along the dock where two barges could be unloaded at one time by two cranes. The capacity of the bins was 2,800 cubic yards, divided into 350 cubic yard compartments, each feeding onto a belt conveyor for the delivery of the aggregates to the nearby mixer plant.

Bulk cement was picked up from the deck of the cargo barge and blown about 200 feet to a 3,000 barrel cement storage bin by a remote-control cement unloader. Two rotary feeder disks delivered cement to a screw conveyor feeder that carried a constant amount of cement to a point where it was boosted through a pipe by hot, low pressure air and conveyed to the bin.

Compartments for sand and two sizes of aggregates were made by longitudinal partitions in the storage bins. The concrete mixers were arranged so that each was charged by individual aggregate, cement, and water batchers. The aggregates were weighed manually on individual beam scales, while cement and water were automatically weighed. Discharge from the batchers to the mixers was electrically controlled to a definite cycle. Water was discharged first. Six seconds later the aggregates were released, and two seconds later the cement was discharged. Five electric-driven, double-drum mixers were located in a line directly under the batcher floor. These mixers, of the type developed for fast-moving paving work, mixed roughly 75 cubic yards of concrete per hour.

Pour operations for Dry Dock No. 4 started March 4, 1941. Concrete was delivered from the mixers directly to the agitator hoppers of double cylinder concrete pumps. A total of eight pumps were used. These pumps, and an equal number of booster pumps, forced the concrete through pipelines about 1,100 feet to special barges equipped for tremie placing. These two barges placed the concrete for the floor and side walls of the dry dock. For the floor, a steel car float, 337 feet long by 47 feet wide, was used with four pairs of building hoist towers, 40 feet high, which carried the concrete pipelines on a platform connecting their tops. The pipelines discharged into fixed hoppers hung between the pair of towers, and these in turn, discharged into sliding hoppers on the face of the towers which connected directly with the 60-ft. long, 12-inch diameter tremie pipes (Anonymous 1942a:48). Generally four pumps were used for concreting the floor area of the dock, and three or four for placing two sections of side wall.

The job manager for the project, D.H. Young, summed up the merits of pipe line transportation of concrete:

> The system was readily adaptable to this job, as it gave a uniform and continuous distribution of unsegregated concrete to the tremie hoppers. The outstanding advantage of the pumping system lies in the coordination that can be effected, as there is no confusion or interference between the place of manufacturing the concrete and the place of deposit. This was very important because the entire job and the location of each working unit at each stage of operation within the dock was plotted and timed, in accordance with a precisely worked out schedule, made months in advance for each day of work. Similarly, the crews assigned each division of the undertaking were painstakingly instructed and trained so that the intermeshing operations would proceed without a hitch when once set in motion (Anonymous 1943b:183-184).

Concrete from the pipelines was discharged into four 2 1/2 cubic yard hoppers, each of which fed two tremie placing pipes. In starting a pour any two of the concrete pipelines were directed to feed into one tremie. Both hoppers were filled with concrete to assure a heavy, constant flow while starting the pour and to prevent loss of a seal. A plug, constructed of a plywood disk covered with a canvas seal and equipped with vertical fins to prevent its turning in the pipe, was used ahead of the concrete as each pour was started to eliminate a rush of water that could wash the cement from the aggregate. The plug, held by a cable, was progressively lowered and was completely released when a column of concrete in the tremie pipe was of sufficient size to provide a seal at its outlet.

Pours on the dock bottom were started either at one end or near the center of the monolith, and other tremies were not used until concrete to a depth of one foot had flown to the adjacent site. A 158 foot width of bottom was poured at one time. Concrete, of the characteristics used, took an underwater slope of about 1 on 9, leaving minor undulations in the concrete surface. These were leveled out in bottom slab placed after the dock was unwatered. It was found practical to pour two sections of the bottom forms daily in four eight-hour shifts. Each shift poured a section containing 1,000 cubic yards of concrete (Anonymous 1943b:184). The tremie concrete floor was completed on June 25, 1941.

The wall concrete was poured using similar methods. Side wall forms measured either 36 or 24 feet long. These forms were built of corrugated sheet steel. Steel channels, placed back to back, served as walers, and 1 1/4 inch bolts served as tie rods. The largest forms weighed 30 tons (Young 1941:47). Two tremie placing devices on each of two barges were used as wall sections on opposite sides of the dock were placed simultaneously. The portions of the walls above the level of 5 feet below low water were built in the dry. To enable this to be done, steel sheet piling was imbedded for a depth of 2 feet in the top of the tremie-poured walls. This piling projected above high-water level and formed a continuous sheeting around the dock, so that it could be unwatered. The top lift of the walls was an intricate concrete section containing utility pipes and power conduits.

The wall sections were poured at an average rate of 60 cubic yards per hour, while simultaneously work was proceeding on the bottom slab. After the bottom slab was completed, it was possible to increase production to about 80 cubic yards of concrete per hour when finishing the wall pours (Anonymous 1943b:184).

The 2 1/2 foot finished floor over the tremie seal of the dock was placed by pumping concrete to the edge of the dry dock and dropping it through spouts to hoppers on the floor for final distribution by concrete buggy. Reinforcing was set and was followed by the placing of inserts to hold the keel blocks. Forms for the 2-foot thick veneer on the walls were lacquered plywood panels, 14 ft. wide, the full height of the docks. Concrete for the wall veneer was delivered by pipeline and dropped through spouts.

Following the completion of concrete placing, the final steps in construction were taken. The caisson gate was completed on January 24, 1942. The second unit of the dry dock was pumped out on January 29, 1942. The temporary cofferdam in the dry dock was removed on February 20, 1942. The dry dock was completed in May 1942.

The contractor for the two Philadelphia dry docks, as well as the Norfolk dry dock, was Dry Dock Associates, a combination of three contracting firms: Spencer, White and Prentis, Inc., Foley Brothers, Inc. and Merritt-Chapman and Scott Corporation (Anonymous 1943b:166). The engineers for the project were Dry Dock Engineers whose constituent members were four firms based in New York City: Frederic R. Harris, Inc.; Parsons, Klapp, Brinckerhoff and Douglas; Moran, Proctor, Freeman and Mueser; and Fay Spofford and Thorndike (Anonymous 1943a:124). The main office of Dry Dock Engineers was at the offices of Frederic R. Harris, Inc., 37 William Street. Construction of the dry dock was undertaken by a combination of four firms: Walsh Construction Company, J. Rich Steers, Inc., the Cauldwell-Wingate Company, and the Raisler Corporation. The project manager for Dry Dock No. 4 was Frederic B. Spencer, while the job manager was Dan H. Young. Byron Hunicke and Jack Aroyan were in charge of design, and Joe Wigmore was in charge of architecture (Young 1941:105).

Photographs in the collection of the National Archives document an October 1946 overhaul of the caisson. This overhaul included the installation of end fenders and a rubber gasket covering the seat timbers.

Frederic R. Harris

The primary consulting engineers for Dry Dock No. 4 were Frederic R. Harris, Inc., of which Rear Admiral Frederick R. Harris (CEC) USN, Retired, was president. Harris originated, in about 1927, the technique of dry dock construction using the underwater tremie method.

Prior to the development of the tremie method, the construction of a dry dock was often a long, costly, and sometimes disastrous process. A typical dry dock took up to ten years for construction. Harris cited the reasons that he developed the tremie method:

> It can readily be seen that digging a hole at tidewater some 60 or 70 ft below the water surface and some 1,000 ft long and over 150 ft wide, is a hazardous undertaking, difficult to estimate. Also, if the enclosing basin can be built under water, and without having to exclude water, or if it can be built above the water and lowered into place, much of the hazard and uncertainty will be eliminated. The tremie method seeks to solve some of the difficulties (Harris 1942:309).

Harris first used the tremie method in 1927 to construct the outshore end of a graving dock, built for the Robins Dry Dock and Repair Company in Erie Basin, New York. The outboard end of this dry dock projected into the open water, where the subsoil consisted largely of a very fine running sand in which boulders were imbedded. The use of the tremie process allowed the construction of the dry dock well within its original cost estimates and its completion within two years (Harris 1942:309-310). The first major Naval project to use the tremie method was a dry dock designed by the Bureau of Yards and Docks at Pearl Harbor, Hawaii (Harris 1942:310). The successful completion of the Pearl Harbor dock was followed by the construction of smaller, shallower docks using the tremie method, again at Pearl Harbor and at Mare Island, California (Harris 1942:311). These projects provided ample experience for construction of the twin dry docks in Philadelphia.

Harris described the rationale behind the construction plan for the Philadelphia dry docks:

> When the first Philadelphia dry dock was proposed, initial designs showed that an extension or improvement over the previous methods by the use of tremie walls would result in a more economical design and a more expeditious construction procedure. The side wall cofferdams as at Pearl Harbor...proved to be a slow and hazardous operation, and the simple method employed for the twin destroyer docks...could not be used without thickening the floor and introducing extensive and impractical bracing supports for the sheet piling.....
>
> The reason for using tremie-placed walls was to complete as much of the concreting as possible prior to backfilling and unwatering of the site, thereby advancing the completion date. Another advantage was that by lowering the water in the dock area to just below the top of the tremie walls, it was possible to complete the top of these walls and the backfill before pumping out the rest of the water, which would act as ballast on the floor, if required (Harris 1942:311).

Harris had founded his own engineering company in 1927. He had graduated from Stevens Institute of Technology in 1896 and spent the first portion of his career in private engineering practice. In January 1903, he was commissioned a Lieutenant (junior grade) in the Civil Engineer Corps of the U.S. Navy. He held a variety of engineering and construction positions in the Navy at the Charleston, New York and Philadelphia naval shipyards, at Pearl Harbor Hawaii, and at Guantanamo, Cuba.

In 1916, he was appointed Chief of the Bureau of Yards and Docks of the Navy and Chief of Civil Engineers. In this capacity he had charge of all public works in preparation for and during the first months of U.S. participation in World War I. In 1918, he was appointed president of the Board of Control of War Construction Activities at Hampton Roads, Virginia.

During World War II Admiral Harris served as consulting engineer to the Navy. He designed the world's largest floating dry docks, as well as shipyards and repairs yards for the shipbuilding industry and for the expansion and rehabilitation of many navy yards. An authority on graving (dry) docks and floating docks, Admiral Harris wrote extensively on the subjects in technical journals and lectured on them at several colleges and universities (Anonymous 1949).

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Collection of approximately 100 engineering drawings on microfilm. These drawings were primarily prepared by Dry Dock Associates, Inc. and Frederic R. Harris, Inc., 1941, and some duplicate those on file at Building No. 501. RG 71, microfilm roll 98. Cartographic Branch, National Archives, College Park, Maryland.

Historic Views

Two photographs of Dry Dock No. 4 showing scrapping of vessels (1946). In exhibit at National Archives-Mid-Atlantic Region, Philadelphia, titled, "Mainstay of the Fleet: The Philadelphia Navy Yard, 1801-1996."

Approximately 60 photographs of Dry Dock No. 4, 1941 to 1946. RG 71, Prints and Photographs Branch, National Archives, College Park, Maryland. (Representative illustrations are reproduced on pages 23 to 36 which follow.)

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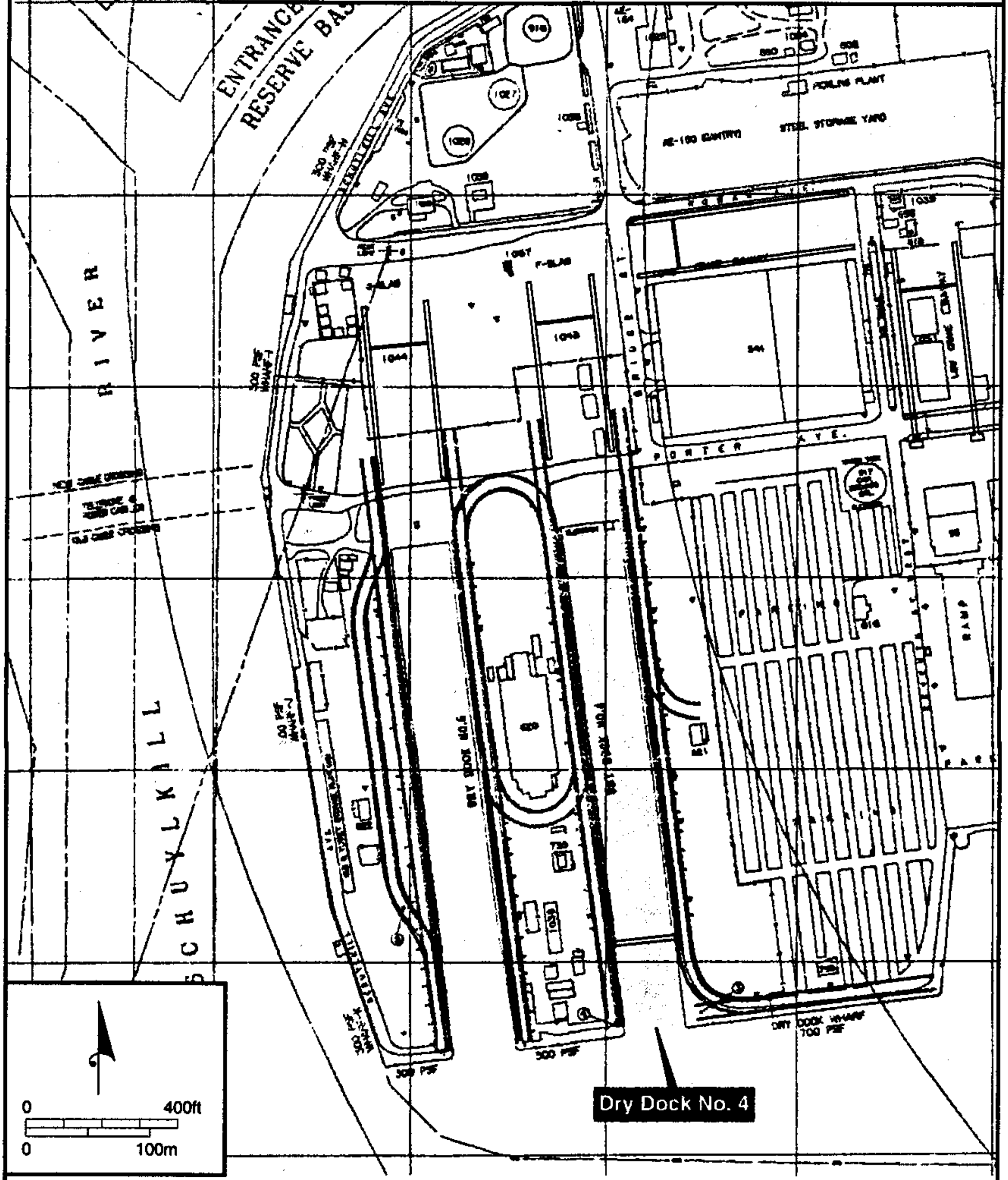
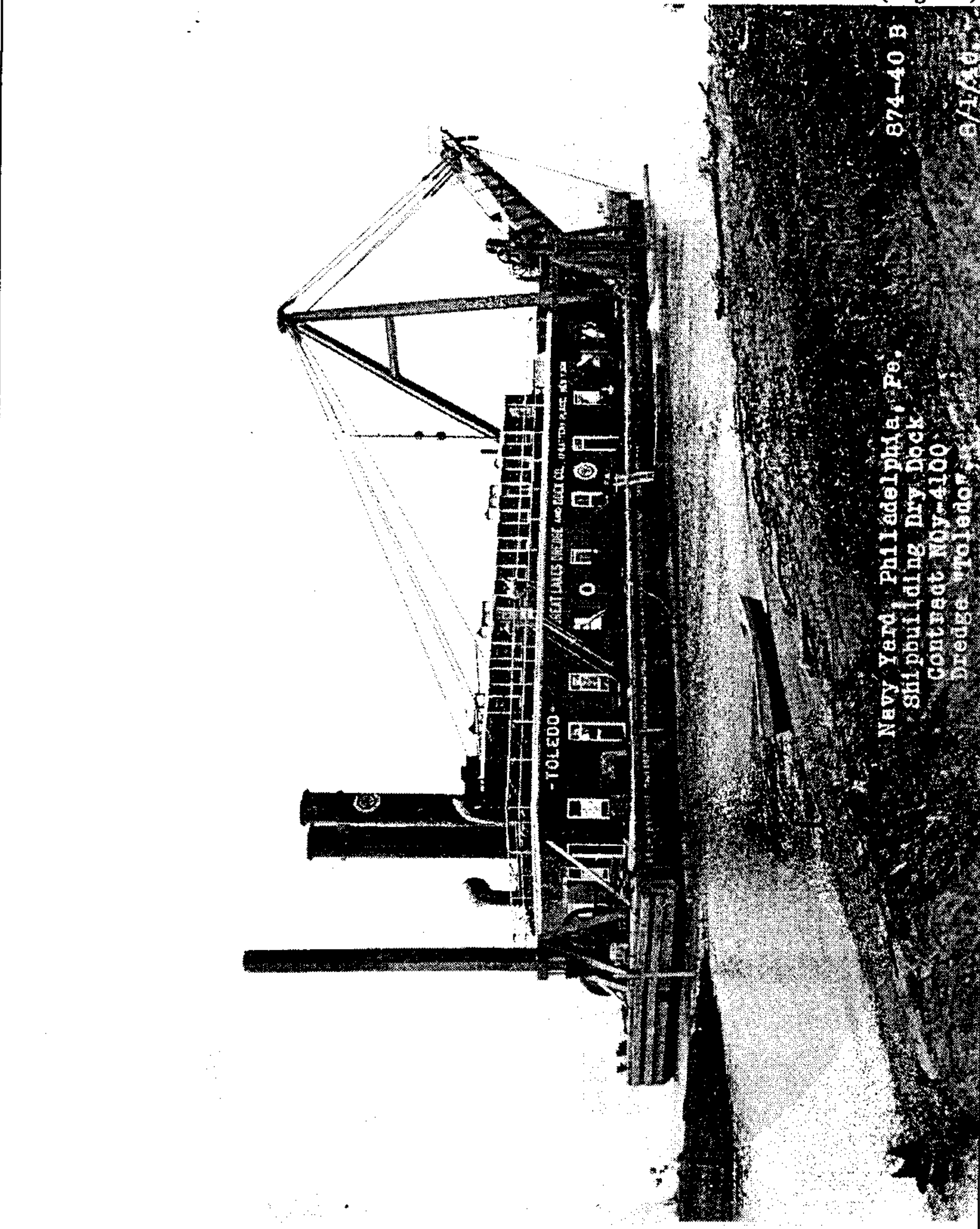


Plan of west end, Philadelphia Naval Shipyard, showing location of Dry Dock No. 4.

Dredge *Toledo* used to dredge the basin for Dry Dock No. 4. August 1, 1940.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)

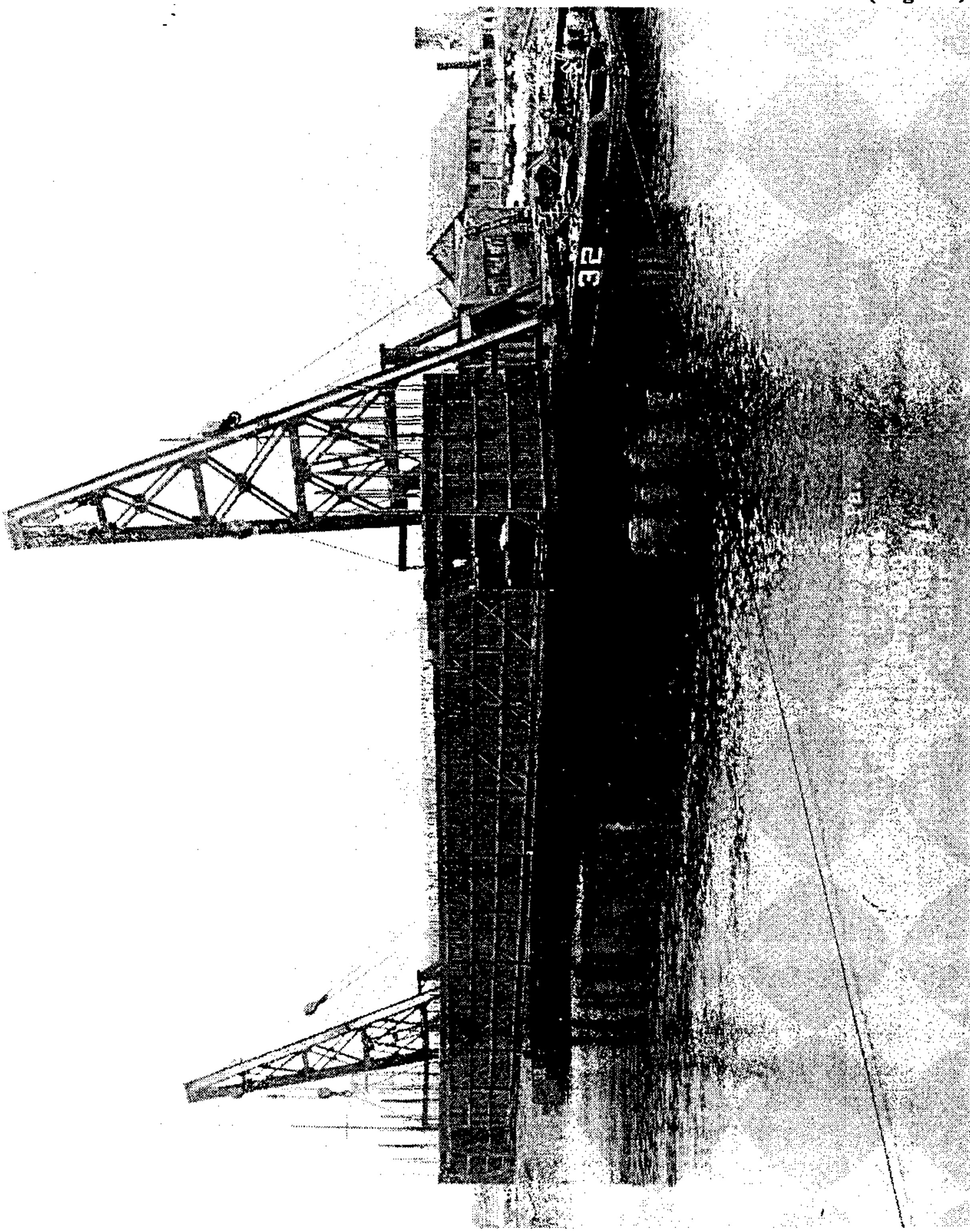


Dredge *Toledo* used to dredge the basin for Dry Dock No. 4. August 1, 1940.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)

Dry dock basin with operating dredge. Looking southwest. October 3, 1940.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)



Placing tremie truss #1. Ready to lower. January 30, 1941.

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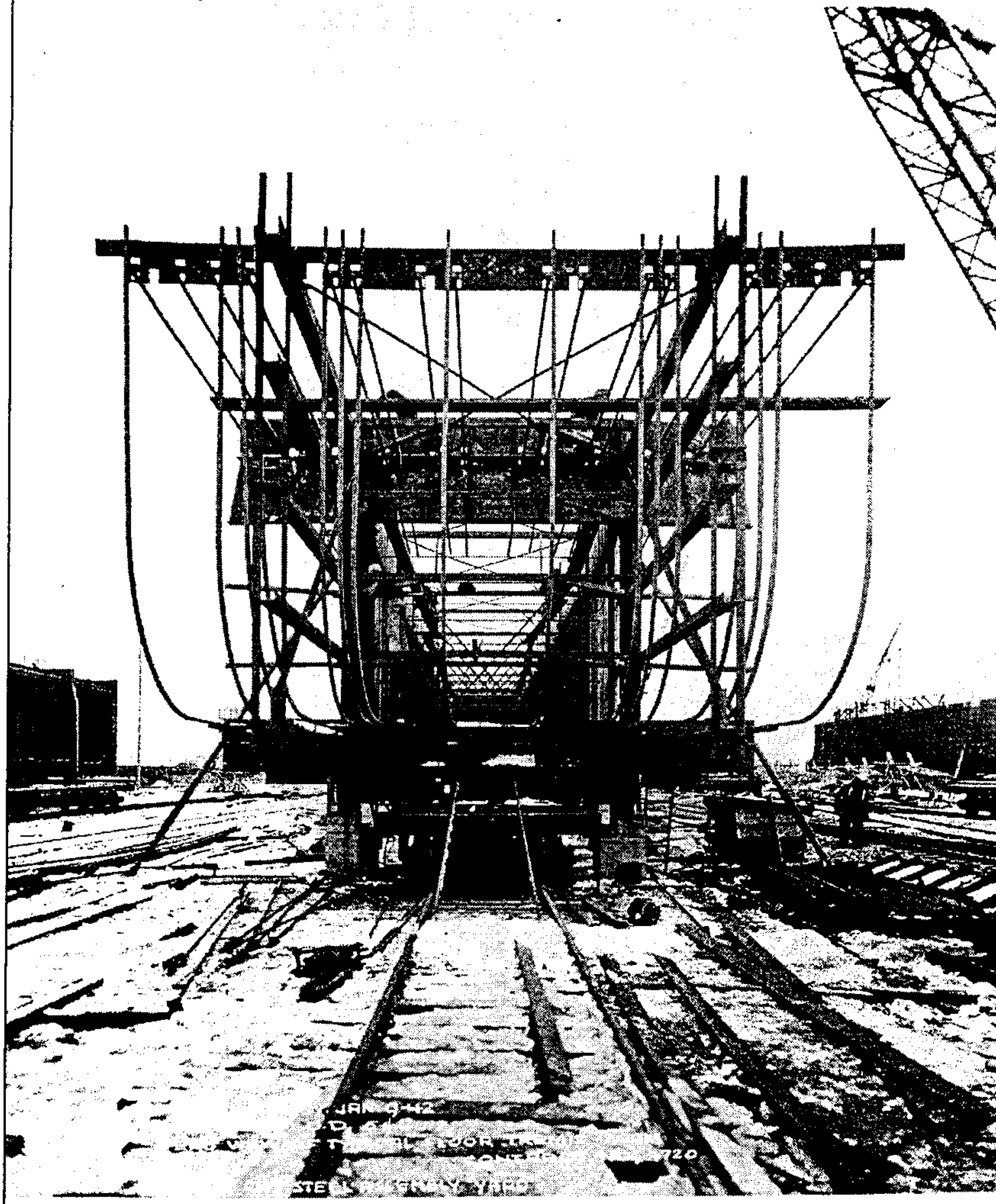

End view of typical floor tremie form. Jersey City Steel Assembly Yard. No date.

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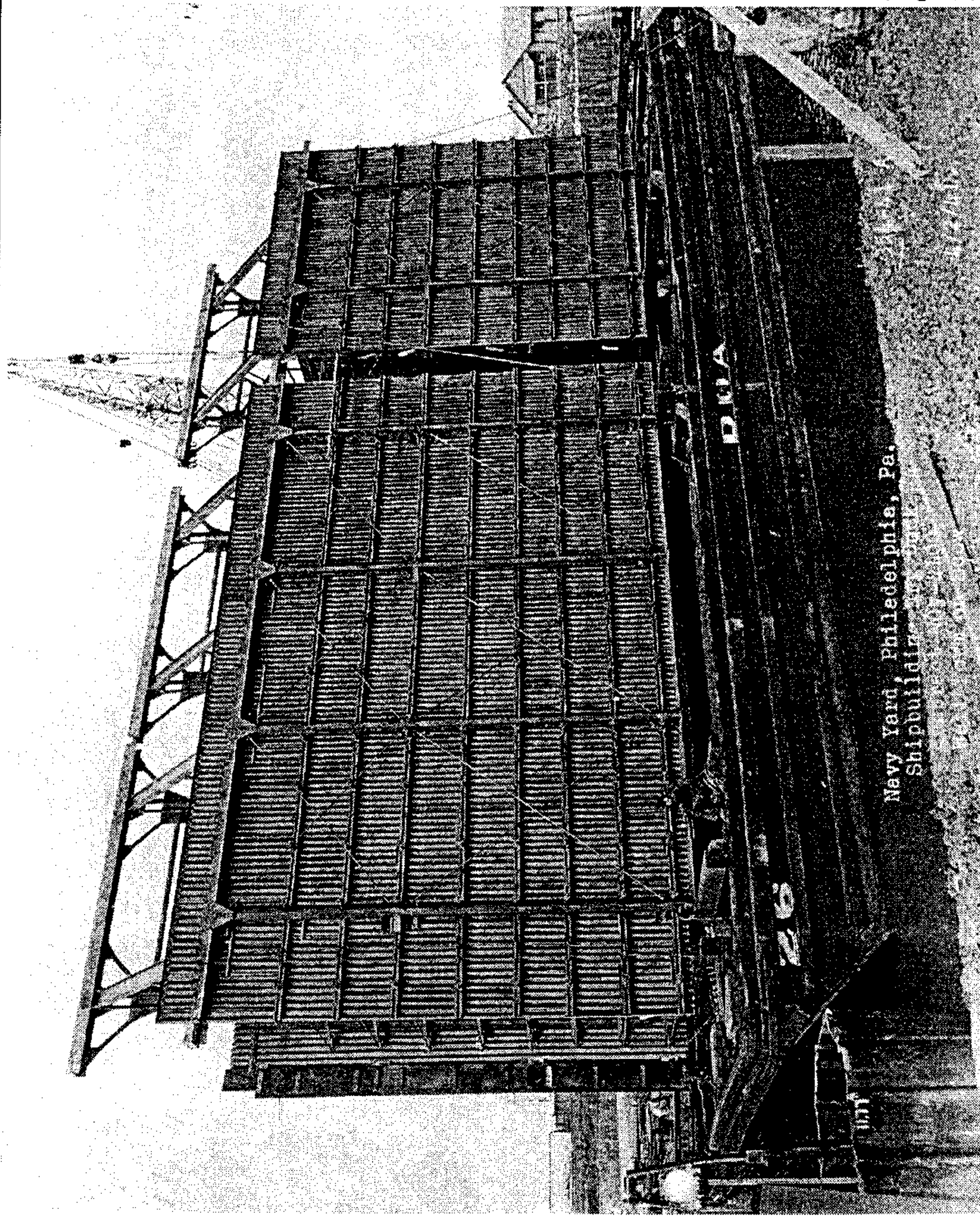
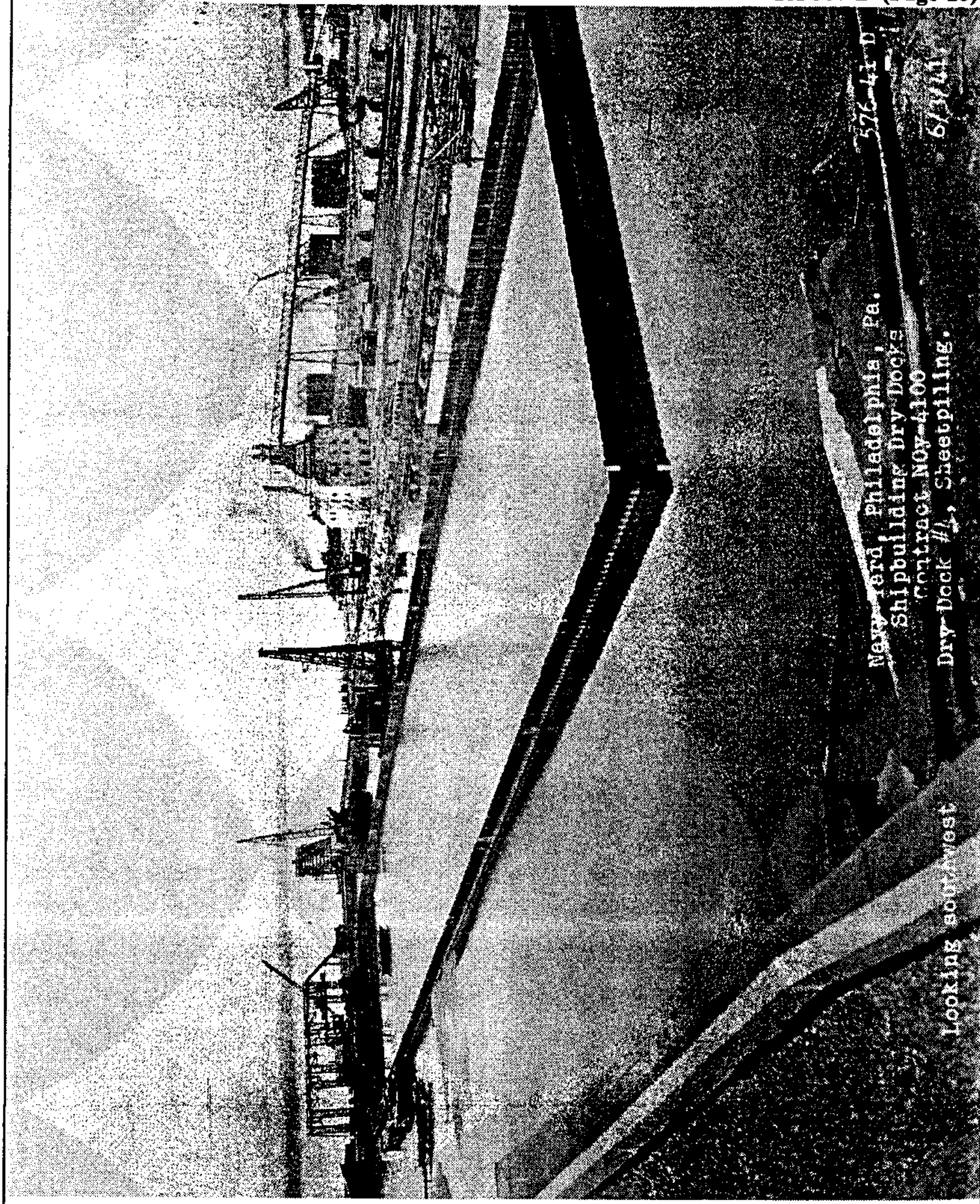


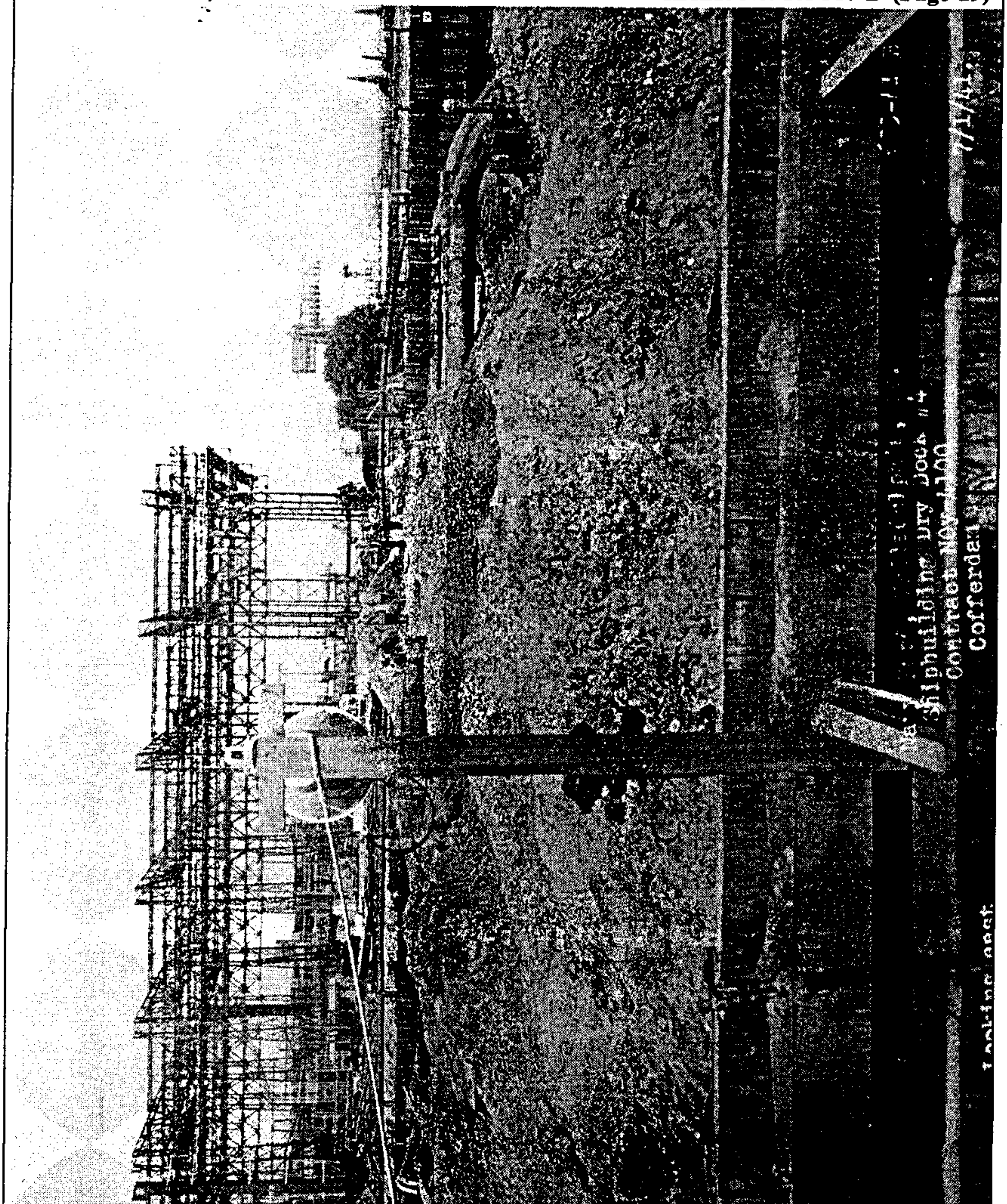
Wall form on scow. April 2, 1941.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)



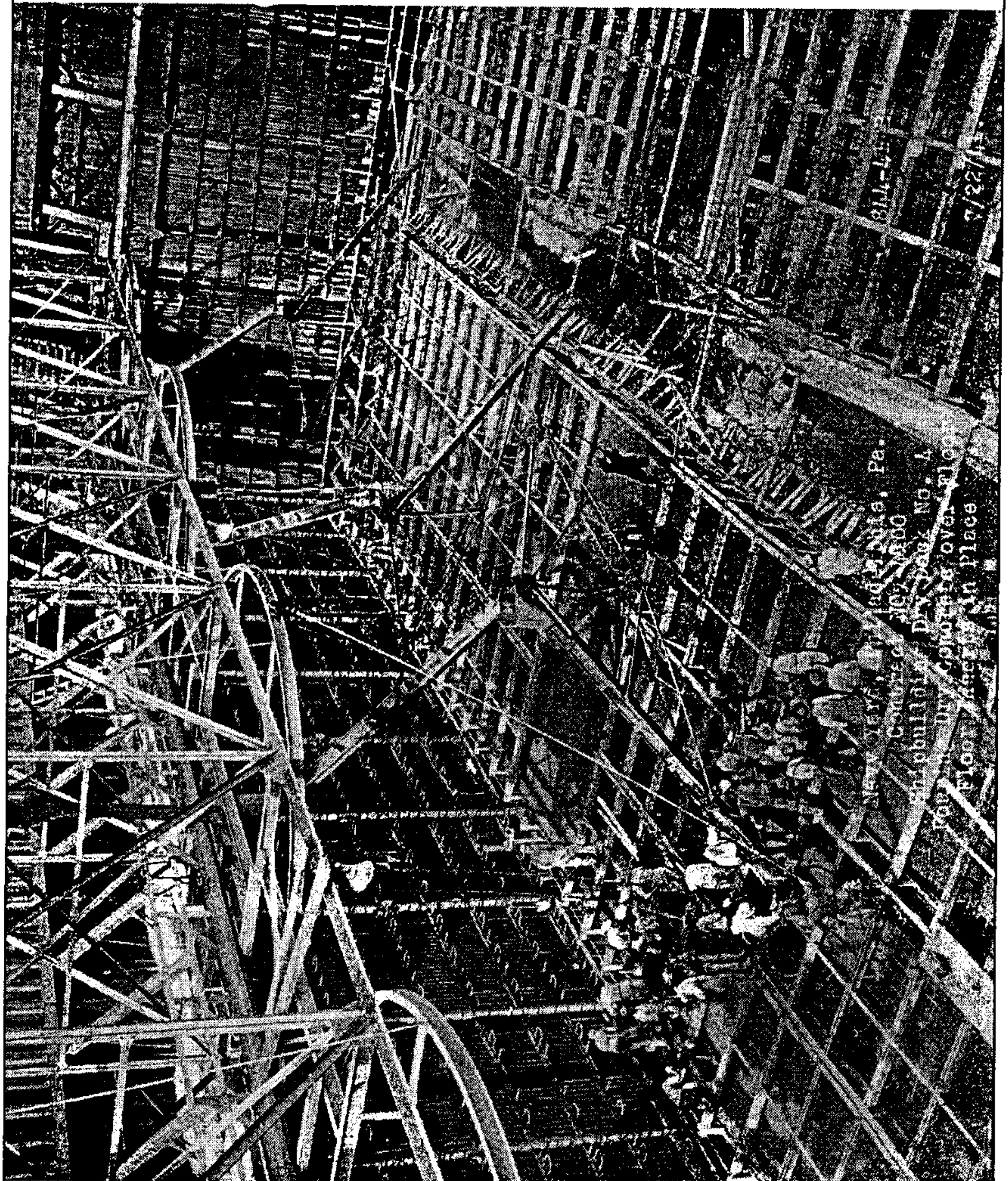
Sheetpiling, Dry Dock No. 4. Looking southwest. June 3, 1941.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)



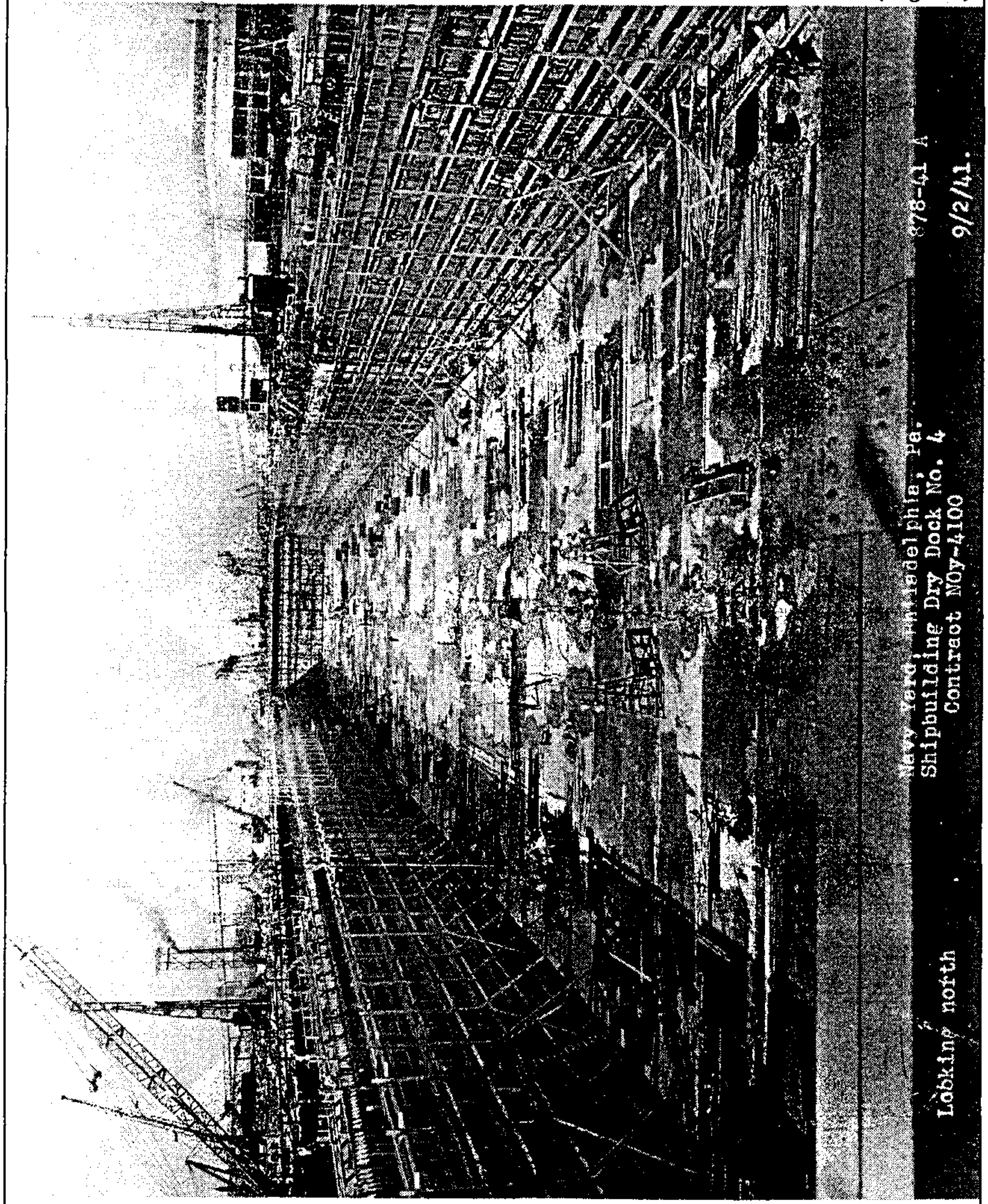
Cofferdam, Dry Dock No. 4. Looking east. July 1, 1941.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)

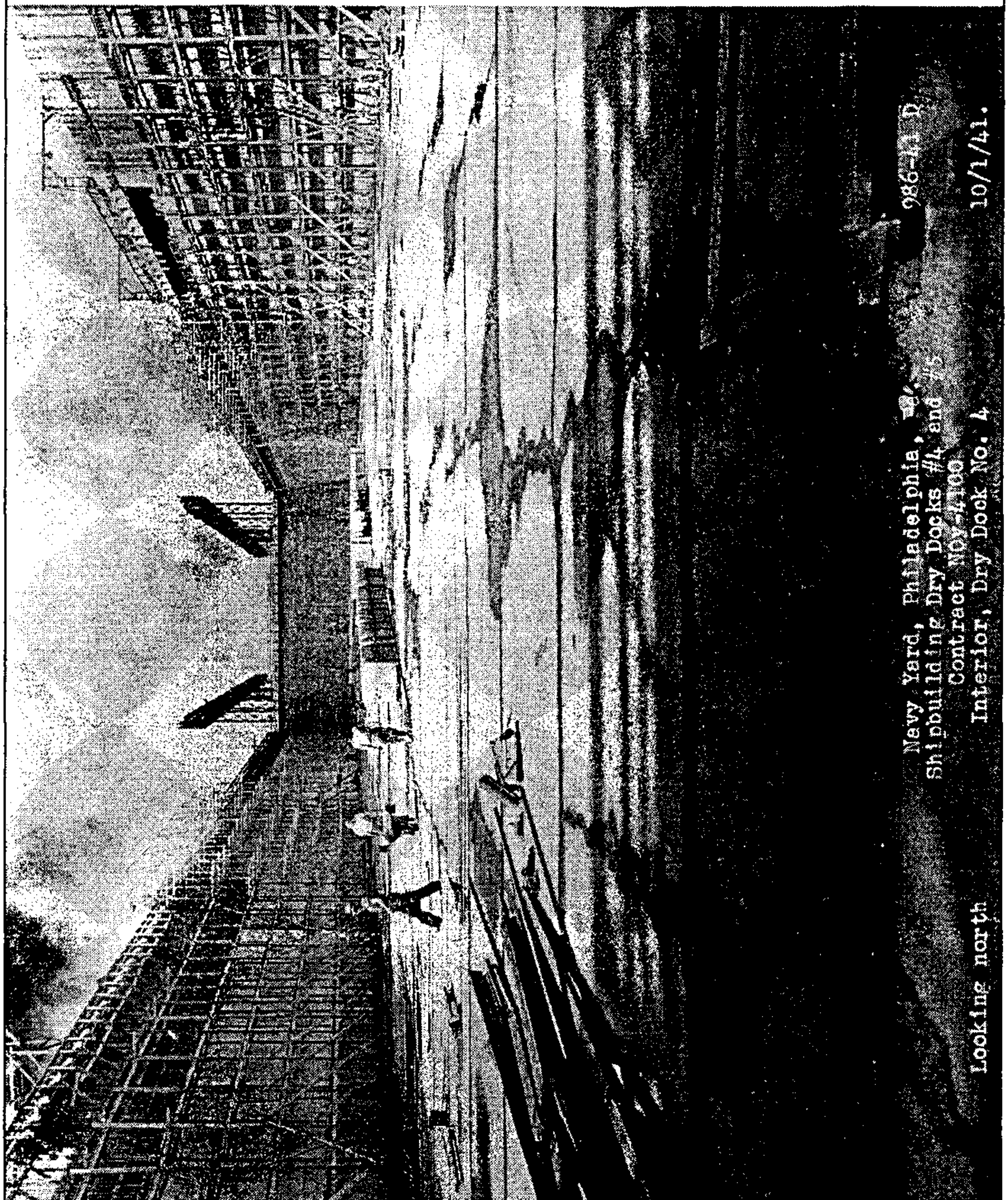


Pouring concrete – finish floor, Dry Dock No. 4. July 22, 1941.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)

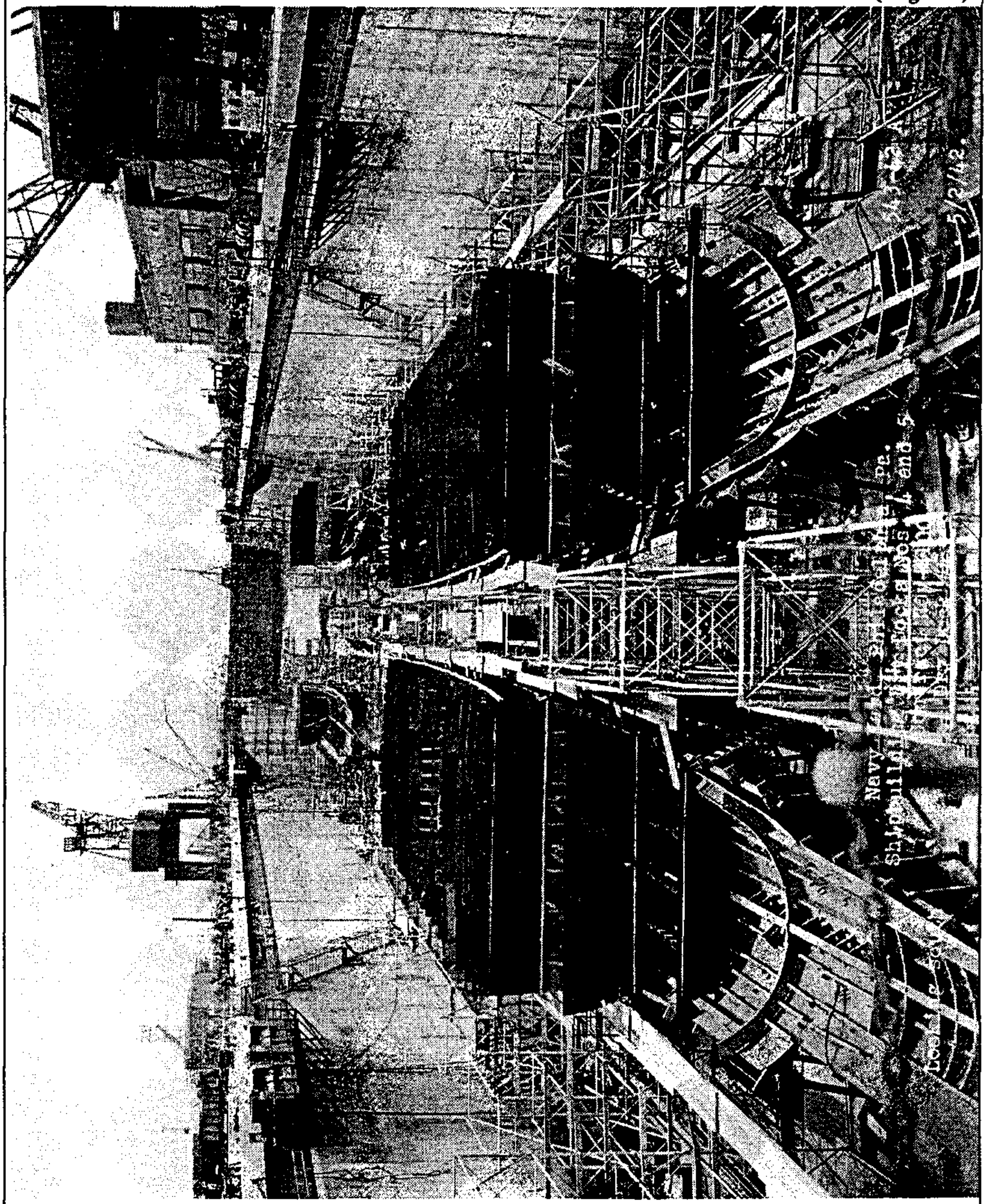


General view of Dry Dock No. 4. Looking north. September 2, 1941.



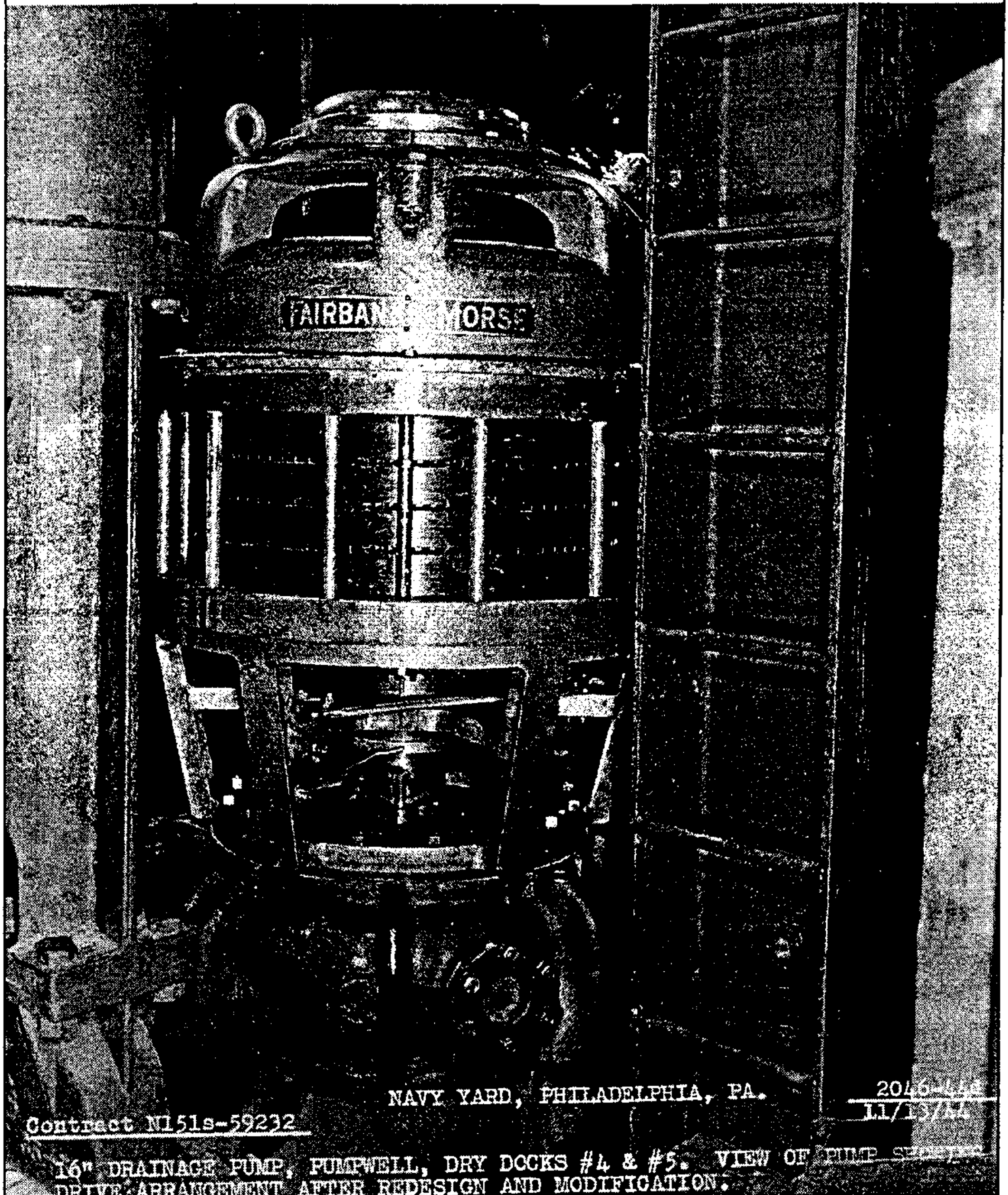
Interior, Dry Dock No. 4. Looking north. October 1, 1941.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)



Ships under construction in Dry Dock No. 4. Looking south. May 2, 1942.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)



16" drainage pump, pumpwell. View of pump showing drive arrangement after redesign and modification. November 13, 1944.

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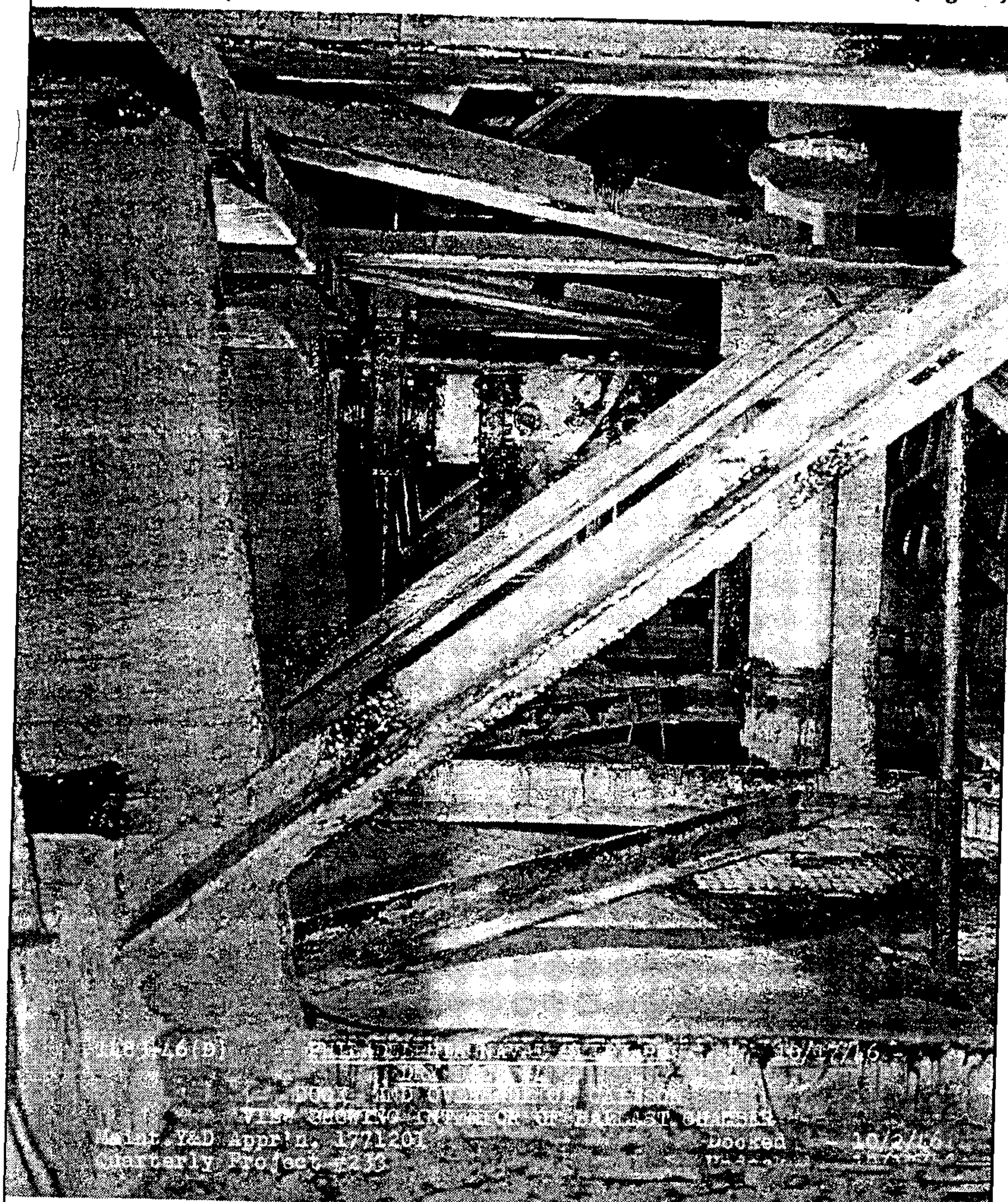
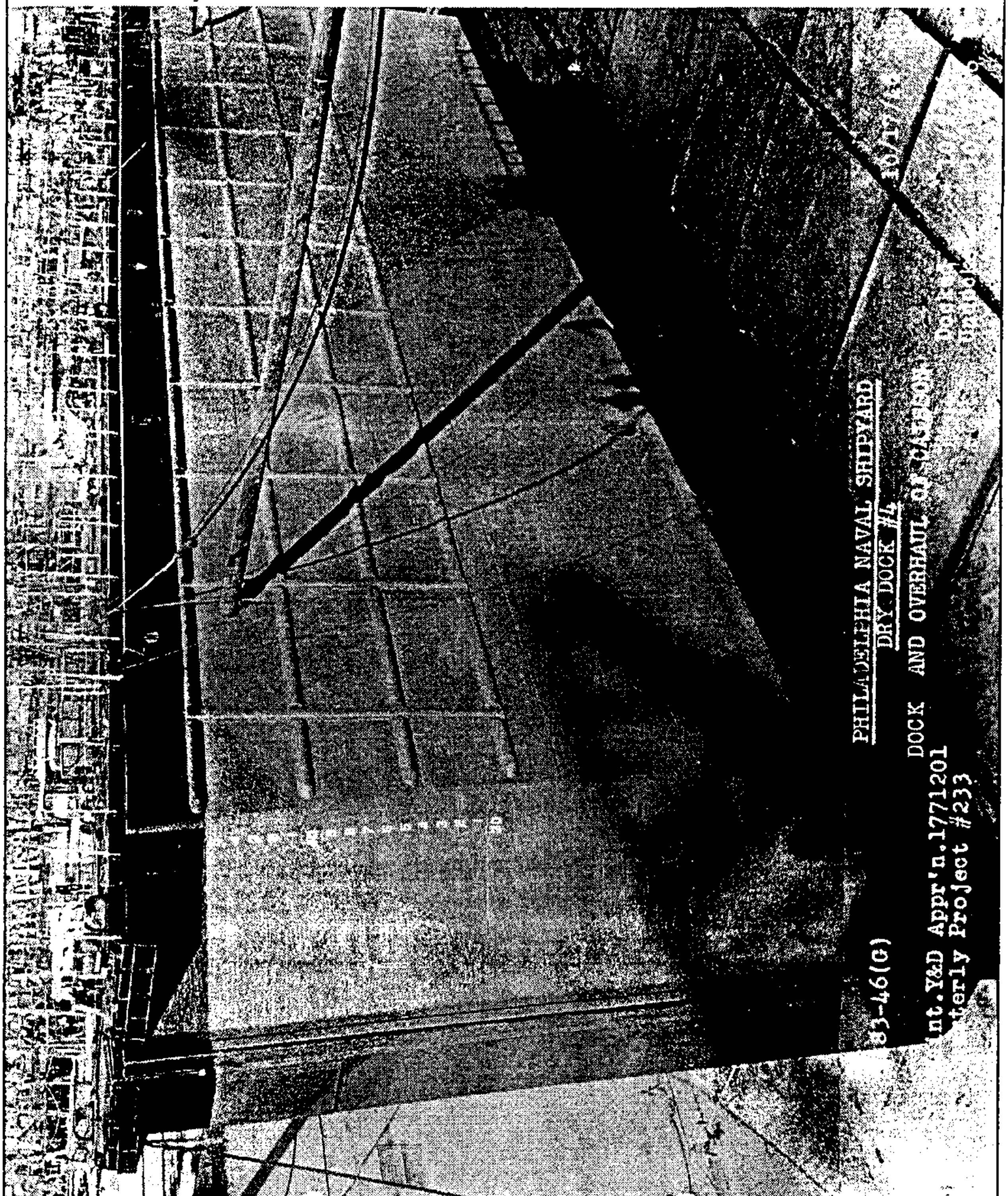


Overhaul of caisson, Dry Dock No. 4. View showing ballast chamber in interior of caisson. October 17, 1946.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)



Oblique view of caisson during overhaul, Dry Dock No. 4. Note walkway atop caisson. October 17, 1946.

Original at Prints & Photographs Branch, National Archives, College Park, Maryland (RG71)